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COMPARISON OF GULF STREAM FORECAST MODEL INITIALIZATION AND VERIFICATION ANALYSES*

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COMPARISON OF GULF STREAM FORECAST MODEL INITIALIZATION AND VERIFICATION ANALYSES*

1.0 INTRODUCTION

The preparation of six, nominally two-week duration case studies for the initialization and verification of Gulf Stream forecast models was begun jointly by Harvard and the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) in 1988. The six case studies were chosen by determining which time periods had both the Regional Energetics Experiment (REX) Geodetic Earth Orbiting Satellite (GEOSAT) underflight Airborne Expendable Bathythermograph (AXBT) surveys and good infrared (IR) coverage. Because of persistent cloud cover over the entire second week of Case 1, this case was immediately shortened to one-week duration.

The original data set for the six case studies included the NOARL IR imagery archive (approximately one image per day), the NOARL analysis of the GEOSAT altimetry using a classified geoid, the REX alongtrack AXBT flights, the weekly Harvard AXBT survey flights, and the archived Fleet Numerical Oceanography Center (FNOC) and National Ocean Data Center (NODC) AXBTs. Because some warm and cold rings can remain unobserved for several weeks at a time, the historical GEOSAT Ocean Application Program (GOAP) and Harvard Open Ocean Model for the Gulf Stream (GULFCAST) real-time analyses were made available to provide historical interpretations of the warm and cold rings locations. The REX and Harvard AXBTs were manually quality controlled by the originating institution before they were made available to this study. The total AXBT data set was then checked by computer for bad AXBTs; however, individual AXBT traces from the combined data set were not plotted. For each case, the data was used to generate three frontal analyses spaced at one-week intervals. The frontal analyses consisted of the Gulf Stream axis location and the warm and cold ring locations, sizes, and maximum swirl velocities. Since relatively little data is available on the ring swirl velocities, the estimates were based largely on estimates of ring age. The analysis domain extended from approximately 74W to 54W, and the evaluation domain from 73W to 53W.

At this point the Harvard and NOARL analyses diverged. A final set of frontal analyses were prepared separately by Harvard and NOARL for the six case studies for use in each institutions validation study. NOARL used their archived IR image files to determine cloud-free periods in which their existing archive was incomplete, and ordered additional IR data from the National Oceanic and Atmospheric Administration (NOAA). NOARL then updated the joint analyses with the additional data. When no new data was obtained for a specific analysis, the preliminary analysis was used. Also, cloud cover in a critical region caused NOARL to shorten Case 6 to one week.

Harvard performed a separate re-analysis of the NOARL IR imagery archive data, and further quality controlled the REX, FNOC, and NODC Expendable Bathythermographs (XBTs). Harvard prepared error bars based on the jointly specified criteria for each of the frontal analysis they performed. Harvard then adjusted some of the analysis days to maximize the available data and reduce the overall error bars. The NOAA analysis of the IR imagery, which is a two-day composite analysis, was then used to fill in the remaining data gaps. Because it is a two-day composite analysis, the error bars used for this data set were 30 km. To avoid using climatology to fill in data gaps, Harvard shortened Case 2 to one week. Discussion of the preparation of the Harvard error bars can be found in the GULFCAST Navy Operational Gulf Stream Model (NOGUFs) Validation Study report.

Preliminary comparisons of the NOARL analysis with the Harvard analysis indicated that, although some analyses agreed quite well, others were very different. The Institute for Naval Oceanography (INO) wanted to use these data sets, but when differences were observed, INO sponsored the working meeting reported on here.

2.0 COMPARISON PROCEDURES

The comparison of the NOARL and Harvard Gulf Stream validation study analyses was conducted at the INO by Scott Glenn, Dick Crout, and Louise Perkins. Scott Glenn and Dick Crout were involved in both the joint preparation of the preliminary analyses, and in the separate preparation of

the "final" validation study analyses. Louise Perkins acted as an independent participant in the comparison.

The NOARL and Harvard analyses were compared for Gulf Stream axes location, and warm and cold ring characteristics and location. Comparisons of the NOARL Gulf Stream axes with the Harvard Gulf Stream axes (including error bars) were used to identify regions where the two data sets did not agree. These comparisons are attached for easy reference.

The same 15 km range was used in the NOARL study as a range within which perturbations about their initial state were studied for sensitivity. It is important to note that, while most of their studies showed a robust response to such perturbations, this was not always the case. Hence, we note that, although these are the best data sets we can construct today in this region, our error bars may be too large to always predict or forecast meaningfully. Some dynamical footprints are not yet captured well enough to predict their future behavior.

The actual initialization and verification fields then were used to compare a) the Gulf Stream meander shapes used in the actual forecasts; b) the number, location, size, and strength of warm and cold rings; and c) the ring locations relative to the Gulf Stream.

The initialization and verification fields used by Harvard and NOARL can be found in the validation study reports submitted by each group. The systematic case-by-case comparisons made at the INO are summarized here. The NOARL facilities were then used to take a second look at the NOAA and NOARL IR images to determine which differences could be easily resolved and corrected, and which differences would remain unresolved. The NOARL GEOSAT data, although not accessible during this meeting, is still available and can be checked by Dick Crout at a later date. We believe that the identification of regions that could not be resolved is as important, if not more important, than identifying the regions where we could resolve the differences.

3.0 CASE STUDIES

Case 1 August 10, 1985

Gulf Stream: Both analyses agree on the number of meanders. The locations of the meanders between 66W and 60W are shifted. There are no ring formation or absorption events in this case. It is a simple test of the forecast model's ability to handle large propagating meanders, so the initial locations of these meanders is critical to this test.

Warm Rings: Harvard has an additional ring near 59W, well away from the Stream. There are slight differences in the location and strength of the other rings.

Cold Rings: The location of the eastern most cold ring differs by 3 degrees of longitude.

Adjustments: NOARL IR images indicate that the Gulf Stream axes should be within the Harvard error bars.

August 17, 1985

Gulf Stream: General agreement between the two analyses throughout the domain.

Warm Rings: Same comments as above.

Cold Rings: Same comments as above.

Adjustments: None.

Case 2
November 26, 1986

Gulf Stream: The two analyses generally agree west of 54W. The warm ring formation event that occurs over the next week may be sensitive to the actual shape of the meanders between 64W and 62W and the nearby ring locations. New effort should concentrate on lowering the error bars in this region.

East of 54W, the NOARL Gulf Stream flows almost due east along 40N, and has a cold ring interacting with the Stream at 54W. The Harvard Stream dips down to below 38N through the location of NOARL's cold ring.

Warm Rings: NOARL has two additional warm rings based on the GOAP historical locations.

Cold Rings: The cold rings located near 60W and 70W are different in the two analyses. NOARL also has the previously mentioned cold ring in the location of the Harvard Stream near 54W.

Adjustments: Two new NOAA IR images are available on November 25. The eastern edge of the swath is at about 54W, so there is no new data on outflow. The new data did help define the shape of the meanders between 62W and 65W. The small crest in the NOARL Stream near 64W should be reduced and shifted to the west within the error bars. The best estimate of the north wall was digitized from the new images. A good location for the warm core ring was obtained at 41.7N, 63.2W. New data on December 3 resolves the ambiguity east of 54W. The Gulf Stream does dip below 40N through the cold ring in NOARL's analysis.

December 3, 1986

Gulf Stream: West of 61W, the two analysis are similar. The NOARL analysis is slightly farther north in the western region, and slightly farther south in the central region. East of 61W, the analyses are in total disagreement. The Harvard analysis has two very large meanders, while the NOARL analysis is almost straight. Near 54W, both Gulf Streams now dip down through the location of the possible cold ring. The NOARL

analysis still has the cold ring in it near 54W, with the Gulf Stream running through the middle.

Warm Rings: Same comments apply.

Cold Rings: Same comments apply.

Adjustments: New NOAA IR from December 3 indicates that the Gulf Stream north wall is located near 38.9N, 53.6W. The Gulf Stream does dip down at this longitude. The cold feature is slope water, not a cold ring. The image has a piece of Gulf Stream visible between 58.4W and 56.5W that agrees with the NOARL analysis in this region. Farther downstream, the large meander or warm ring between 56W and 54W is partially obscured. It looks more like a warm ring, but we cannot see the Gulf Stream through the partial cloud cover.

December 10, 1987

Gulf Stream: This case was dropped by Harvard due to a lack of data to remove the effect of climatology. The NOARL analysis looks suspiciously smooth for the Gulf Stream. The Gulf Stream still runs through the cold ring near 54W.

Warm Rings: Same comments apply.

Cold Rings: Same comments apply.

Adjustments: Edge of the swath in the new NOAA image for December 10 is at 64W. No new information is available for this analysis. It should be dropped.

Case 3 April 6/8, 1987

Gulf Stream: Harvard found that moving the starting date to April 6 allowed for more data in their data set to be included. Even so, this analysis has the largest error bars of all, 53 km. Throughout the entire domain, the Harvard analysis is shifted north of the NOARL analysis. There

is considerable disagreement in the analyses in the eastern half where the error bars are largest and the large tight meanders undergo significant evolution. NOARL has a large trough at 59W; Harvard's is almost nonexistent. The meander crests at 58W and 56W have very different shapes. The NOARL meanders interact with the warm eddy to the north, while the Harvard meanders interact with the cold eddy to the south. After 56W, there is little agreement at all.

Warm Rings: NOARL has three additional warm rings near 65W,41N; 62W,41N; and 61W,41N.

Cold Rings: NOARL has one additional cold ring at 68W,35N.

Adjustments: Based on the first April 6 image, clear imagery is available between 65W and 69W. At 69W, the NOARL Gulf Stream location is correct and should be used instead of Harvard. At 67W, the meander trough is too deep and Harvard's location should be used. From 68W to 65W, both analyses agree with the data. The small scale meander near 59W in the Harvard analysis is correct. The two small features near 66W labeled cold eddies are clearly visible. The northern one definitely is a cold eddy located at 37.3N, 64.7W. The center of the other feature is at 36.3N, 65.3W. Other cold eddies are visible at 34.6N, 65.7W and 38.4N, 56.8W. The large warm ring at 39.05N, 67.8W is clearly visible with a radius of 90 km.

Based on the second April 6 image, from 64.6W to 61.9W the NOARL and Harvard analyses agree. This image can be used to narrow the error bars to 15 km in this region. The eastern side of the meander near 56W is correctly placed by NOARL based on this image.

Major differences in some features still remain.

April 13/15, 1987

Gulf Stream: A major difference is found in the meander crest at 58W. Harvard's crest is rounded; NOARL's is peaked and extends farther north. Harvard has a larger amplitude meander crest near 70W-69W. Anything east of 54W totally disagrees.

Warm Rings: NOARL has retained the same three warm rings missing in Harvard's analysis. The warm ring at 54W in Harvard's is not in NOARL's.

Cold Rings: Cold ring at 68W is still in the NOARL analysis and not in Harvard's. The two small cold rings between 64W and 66W have different relative positions in the NOARL and Harvard analyses. The Harvard positions are closer to the agreed upon locations on April 6/8. The cold ring near 68W that just barely touches the Stream in NOARL is absent in the Harvard analysis.

Adjustments: The only good image available at NOARL is on April 16, and it has already been digitized. However, it is no help here. The discrepancies remain.

April 20/22, 1987

Gulf Stream: Meanders between 60W and 56W have similar shapes but different locations. Although the NOARL analysis is for two days later, the NOARL locations are upstream of the Harvard locations. This rules out meander propagation as a simple explanation of the difference. The meander trough near 67W is deeper in the Harvard analysis. This is significant, since the deeper meander interacts with the two small cold rings, and the shallow meander does not.

Warm Rings: NOARL has three more rings in the region between 61W and 64W. The latitude of the ring near 56W is different in the NOARL and Harvard analyses.

Cold Rings: The large cold ring near 58W that is interacting with the Stream is in different locations in the Harvard and NOARL analyses. The two small rings between 64W and 66W are in very different relative locations. The historical NOARL ring near 68W is missing from the Harvard analysis.

Adjustments: The April 20 image of the eastern side of the meander near 69W agrees exactly with the NOARL analysis. The NOARL crest near 58W has to be shifted to the center of the error bars. Major differences still remain.

Case 4
May 6, 1987

Gulf Stream: Both nowcasts are within the error bars. The error bars are at least 30 km in most locations. The outflow shapes are very different east of 52W, but the error bars here are huge. The difference at outflow is that Harvard has a cold ring and a warm meander crest, and NOARL has a cold trough and a warm crest.

Warm Rings: Rings near 65W and 62W have slightly different locations, but have little effect on forecast.

Cold Rings: Ring near 72W in the Harvard analysis is 1 degree north of NOARL. NOARL has a GEOSAT-derived ring near 68W interacting with the Stream that is absent from Harvard. This ring follows through all the analyses. The ring at 58W is stronger in the Harvard analysis.

Adjustments: May 5 image has a warm ring at 40.0N, 61.7W. No imagery available east of 52W. Additional imagery from May 3, 4, 5, 6, and 7 provide no more help.

May 13, 1987

Gulf Stream: Trough at 66W is shifted, but the shape is the same. Trough at 53W is shifted. Harvard analysis is shifted downstream of NOARL.

Warm Rings: The warm rings agree very well. The ring at 66W is almost in the same place, but the Stream is shifted so that it is very close in Harvard, and far away in NOARL. The ring at 62W in the Harvard analysis is shifted south in NOARL by 0.5 degree, but it does not effect the forecast.

Cold Rings: Cold ring at 35N, 69W is missing in the Harvard analysis. Cold ring near 51W in Harvard analysis is outside of NOARL domain.

Adjustments: The May 11 image indicates that there may be a cold eddy at 35.4N, 68.6W, but it is weak. Data is inconclusive on the warm ring

near 62W. The eastern side of the meander near 67W agrees with the Harvard analysis. The May 13 image, however, indicates the eastern side is shifted even farther east. There must be GEOSAT crossing on that day which should be checked. The west side of the meander near 53W on May 13 should have its axis half way between the Harvard and NOARL location. The cold ring is at 39.4N and 50.3W. The newly formed cold ring is still elliptical and located at 36.5N, 67.4W.

May 20, 1987

Gulf Stream: The NOARL analysis is generally within the Harvard error bars. Harvard emphasizes the trough 71W. The small crest near 69W in NOARL is not in Harvard. The difference in the trough shape at 64W and 59W is almost within the 30 km error bars. After 56W the analyses diverge again.

Warm Rings: NOARL has a ring at 61.5W, 41N, and Harvard has it at 42.5N. The ring at 57W is touching the Gulf Stream in Harvard but is almost absorbed in NOARL.

Cold Rings: NOARL still has a ring at 69W, 35N that Harvard did not have. The ring at 58W is outside of NOARL domain. NOARL has a cold ring at 54W interacting with the Stream, while Harvard has the ring essentially absorbed.

Adjustments: The Gulf Stream between 61W and 59W is clearly visible in the new NOAA image from May 20. The north wall crosses 40N at 59.5W, exactly half way between the Harvard and NOARL analyses. The new north wall location has been digitized. The cold ring was located at 37.4N, 58.2W. A second image from May 20 indicates that the cold ring being absorbed by the Stream is located at 38.2N, 62.0W. This eddy cannot be located in the imagery around May 13. The Stream curves around to the east towards the eddy. The north wall location was redigitized.

Case 5
July 7/8, 1987

Gulf Stream: There are tight error bars on the Harvard analysis for July 7. The NOARL analysis was performed on July 8. There is major disagreement on the formation of a cold ring near 58W. Harvard has a deep meander based on IR from July 7. NOARL has a cold ring in their analysis on July 8.

East of 56W, the Harvard analysis is shifted farther north than the NOARL analysis. West of 58W, the agreement is excellent.

Warm Rings: The small ring near 74W is 1 degree farther south in the Harvard analysis, touching the Stream. The strength of the ring near 71W derived from GOAP history is much stronger in NOARL. The GOAP historical ring near 66W does not appear in Harvard. The ring at 52W in Harvard is not in NOARL since it is east of the validation domain.

Cold Rings: The ring near 70W is shifted northeast by 1 degree in NOARL. The historical ring in NOARL near 63W is not in Harvard. The ring at 58W in NOARL is a meander trough in Harvard.

Adjustments: The feature near 58W most definitely is a large, cold meander trough on July 7 as confirmed in two images. The image on July 8 indicates that the trough is in the process of pinching off, and that the NOARL interpretation for this date is also valid. The cold ring that is forming is tear-drop shaped and not circular. The warm ring at 41.5N, 57.6W is well defined in this image and beginning to interact with the crest to the south. Both the Harvard and NOARL analyses are incorrect east of 52W. The NOAA July 8 image indicated that the large, warm ring in this location actually is a large meander. The north wall of this meander has been digitized. A warm ring location is 37.0N, 73.75W. The warm ring near 71W could not be identified due to clouds. Cold ring information is inconclusive due to clouds.

July 14/15, 1987

Gulf Stream: There is a meander crest at 71W in the NOARL analysis that is absent in Harvard. The meanders between 56W and 62W where the cold ring formation occurred are different. The meander crest that is near 58W in NOARL is at 59W in Harvard. The crest near 62W is very sharp in Harvard. These differences are critical for a ring formation event. Slight differences near outflow are noted. We need to check the IR near 61W-56W, since it makes a big difference dynamically.

Warm Rings: There are differences in the ring location near 74W, but they have little effect on the forecast. The ring at 71W is shifted in the Harvard analysis 1 degree west of NOARL and is weaker. The Harvard location is far enough away not to interact. The ring at 66W is absent in Harvard. The ring at 61W in Harvard is at 63W in NOARL. The large rings at 58W and 52W in Harvard are absent in NOARL. We need to check on the ring near 58W, since it may or may not be absorbed on July 22.

Cold Rings: At 64W NOARL has a historical GOAP ring absent from Harvard. Harvard has one cold ring near 58W, with a cold meander trough nearby. NOARL has a cold ring near 58W, with another cold ring in the location of the Harvard trough. This is the important difference for this analysis.

Adjustments: The July 14 NOAA IR indicates that at 71W, the Stream is farther south than in the NOARL analysis. The meander crest at 71W was based on a bad FNOC or NODC AXBT. The crest should be much lower in amplitude consistent with the IR as in the Harvard analysis. The meanders between 56W and 62W were quite visible, along with a warm ring interacting on the north, and a cold ring near the Stream to the south. The IR north wall and ring locations were digitized for adjustment in this region. The NOAA image indicates that near 58W, there is a deep trough and a single cold ring, not a shallow trough and two cold rings. Warm ring locations are: 37.0N, 74.0W; 39.1N, 68.8W; 39.7N, 71.1W (possible); and 41.3N, 58.1W (interacting with crest). We believe that the large warm ring outside the validation domain near 52W that is present in the Harvard analysis but missing from NOARL actually is a large meander. It has been

digitized. Data is inconclusive on rings between 60W and 66W due to clouds and low thermal contrast.

July 21/22, 1987

Gulf Stream: There is good agreement except at 58W. The NOARL analysis has a large meander formed through an interaction with a ring. Harvard has a straight Stream and a warm ring.

Warm Rings: The ring at 66W based on XBTs in NOARL is missing in Harvard. Harvard has a ring at 61W that is not present or shifted 2 degrees west in NOARL. The Harvard ring at 58W is a meander in NOARL.

Cold Rings: The historical ring at 64W in NOARL is absent in Harvard. The cold ring at 62W is slightly shifted.

Adjustments: There is only one image on July 20 in which the meander/warm ring near 58W is visible between the clouds. The meander is in the process of forming a warm ring. It is a judgment call as to whether or not the ring is actually formed or still attached on July 20. In the image, there is very warm water at the northern edge of the ring, slightly cooler water south of this, followed by warmer water further south. The entire system is surrounded by much colder water. In the July 23 image, a distinct warm ring has definitely been formed. Images for July 21 and 22, the days for the analyses, are cloudy. Since the ring was in the process of forming on July 20, and since it has definitely formed by July 23, we will assume that the ring has formed for the July 21/22 analyses dates.

Case 6 May 4, 1988

Gulf Stream: There is very good agreement over most of the model domain with tight error bars. The only minor disagreement is the larger NOARL meander crest near 58W, and a more peaked Harvard crest near 62W. The GEOSAT data should be checked for this analysis.

Warm Rings: The ring near 54W is closer to the Stream in the Harvard initialization. The ring near 61W that is absorbed by the Stream is weaker in the NOARL analysis.

Cold Rings: Good agreement.

Adjustments: The May 5 image indicates that the meander crest near 62W is peaked as in the Harvard analysis. Imagery east of 60W is cloudy. Both Harvard and NOARL have the relative amplitudes of the warm rings between 61W and 63W correct. The absolute amplitude is unknown. Maybe the altimetry will help determine the amplitude of the meander near 58W.

May 11, 1988

Gulf Stream: There is very good agreement between the analysis from 75W to 53W, but there are large error bars near outflow and some disagreement in the analysis east of 53W. The meander structure between 60W and 54W should be checked for qualitative differences in the amplitude of the meanders within the error bars.

Warm Rings: The warm ring near 61W is interacting with the Stream in Harvard, but absorbed by the Stream in NOARL. The two rings near 59W and 54W are closer to the Stream in Harvard by approximately 0.5 degree.

Cold Rings: The location of the cold ring near 59W should be checked. The Harvard location interacts with both upstream and downstream troughs, while NOARL only interacts with the upstream trough in seven-day forecasts. The ring is about 0.5 degree farther north in Harvard.

Adjustments: Outflow region is not covered by the IR image on May 11. The Stream is very straight in the region between 58W and 54W, in agreement with the second Harvard analysis and the NOARL analysis. The warm ring at 41.3N, 57.0W is visible, but the rings on either side are not visible. The cold ring near 59W is located at 37.6N, 59.0W in this image. The warm ring near 61W is under a cloud. The May 9, 10, and

12 images are no help at all for outflow. The warm ring near 61W is partially visible in the May 12 image at 41.3N, 61.1W.

May 18, 1988

Gulf Stream: Generally larger error bars (30 km) were established for this analysis. There is major uncertainty in the formation of a cold ring near 62W.

Adjustments: The NOAA analysis based on data from May 16-17 indicate that the ring had not yet formed. No NOARL imagery is available from May 17-19. NOARL images are available from May 16 and 20. Both are cloud covered in the region of the possible cold ring formation. We will check the May 16-20 hardcopies to determine if any imagery may have been available. AXBTs are in the area, but are on May 20, and do not resolve the differences in interpretation. No GEOSAT data is available. This case was dropped by NOARL.

4.0 CONCLUSIONS

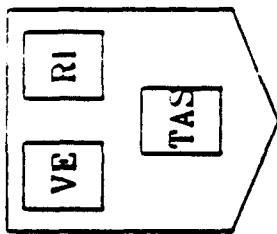
All of the major discrepancies for Cases 1, 4, and 5 have been resolved and have been brought into agreement. Some minor discrepancies remain, such as the locations of some warm and cold rings well away from the Stream.

Similarly, all of the major discrepancies for the first two analyses for Case 6 have also been resolved and brought into agreement. The question regarding whether or not the cold ring formed in the third analyses remains open and most likely will not be resolved, unless additional data are found.

The additional work on the first analysis of Case 2 helped reduce the error bars and fine tune the meander shapes in the critical central region. Additional data for the eastern half of the second analysis is still sketchy.

There is virtually no data for the third analysis, and it is recommended that this analysis be dropped.

The amount and quality of the IR data coverage for Case 3 simply is not sufficient to significantly reduce the error bars on these analyses and to resolve all the discrepancies between the analyses.

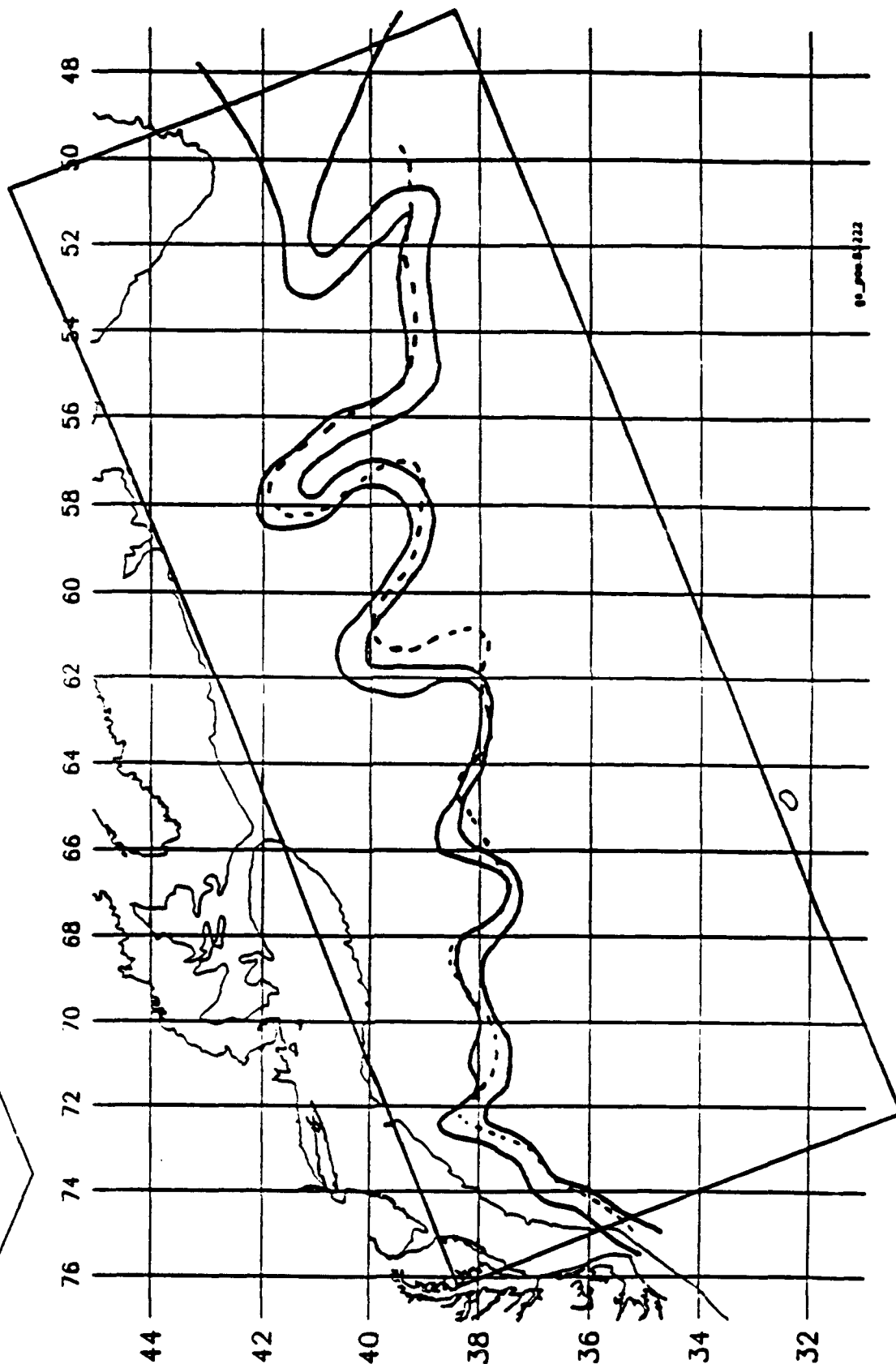


HARVARD UNIVERSITY GULFCAST

HARVARD OCEANOGRAPHIC ANALYSIS.

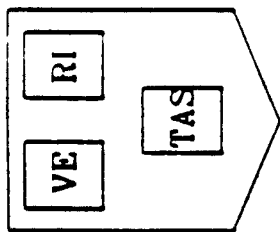
GULF STREAM AXIS ERROR BARS.

FIGURE: NORTHERN & SOUTHERN EXTREMES.



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10 AUG 1985

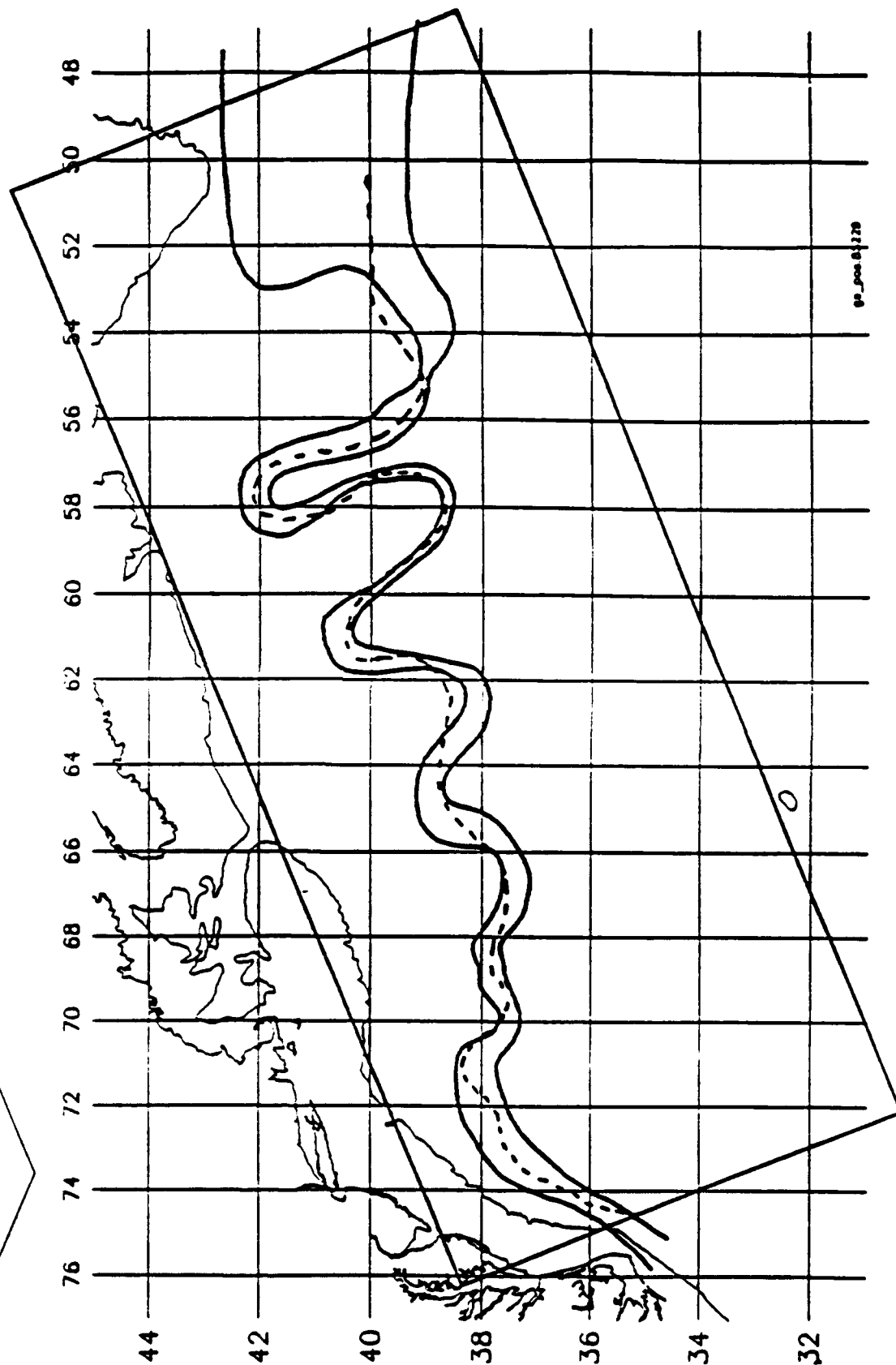


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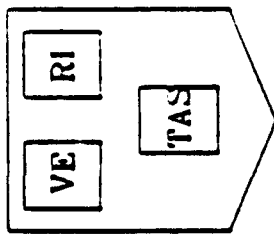
HARVARD OCEANOGRAPHIC ANALYSIS.

GULF STREAM AXIS ERROR BARS.

FIGURE: NORTHERN & SOUTHERN EXTREMES.



17 AUG 1985

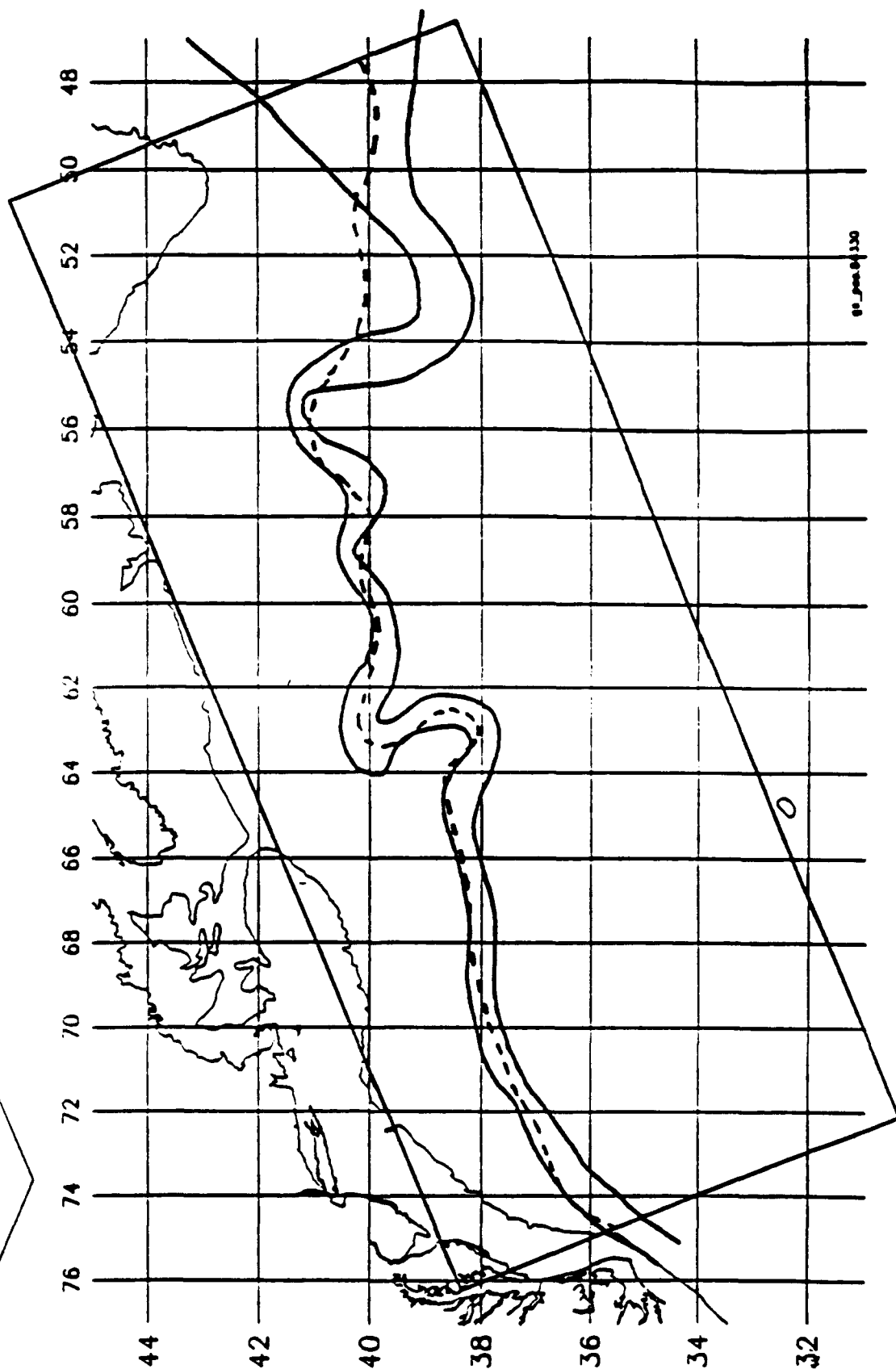


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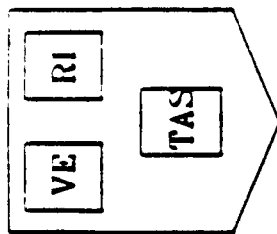
HARVARD OCEANOGRAPHIC ANALYSIS.

GULF STREAM AXIS ERROR BARS.

FIGURE: NORTHERN & SOUTHERN EXTREMES.



26 NOV 1986

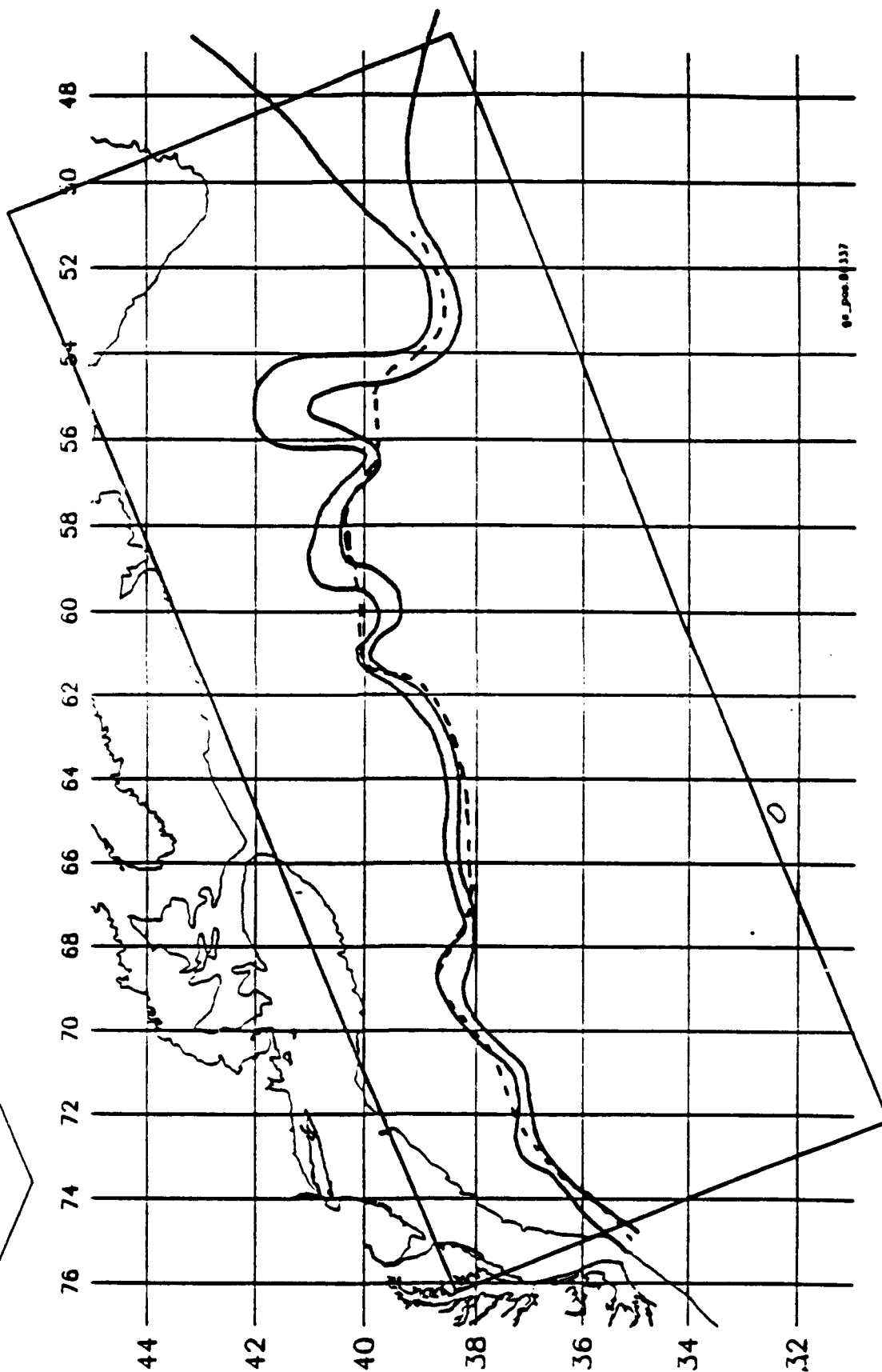


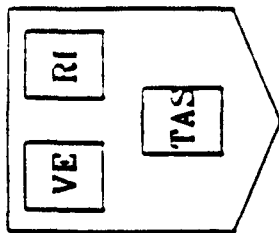
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HARVARD OCEANOGRAPHIC ANALYSIS.

GULF STREAM AXIS ERROR BARS.

FIGURE: NORTHERN & SOUTHERN EXTREMES.



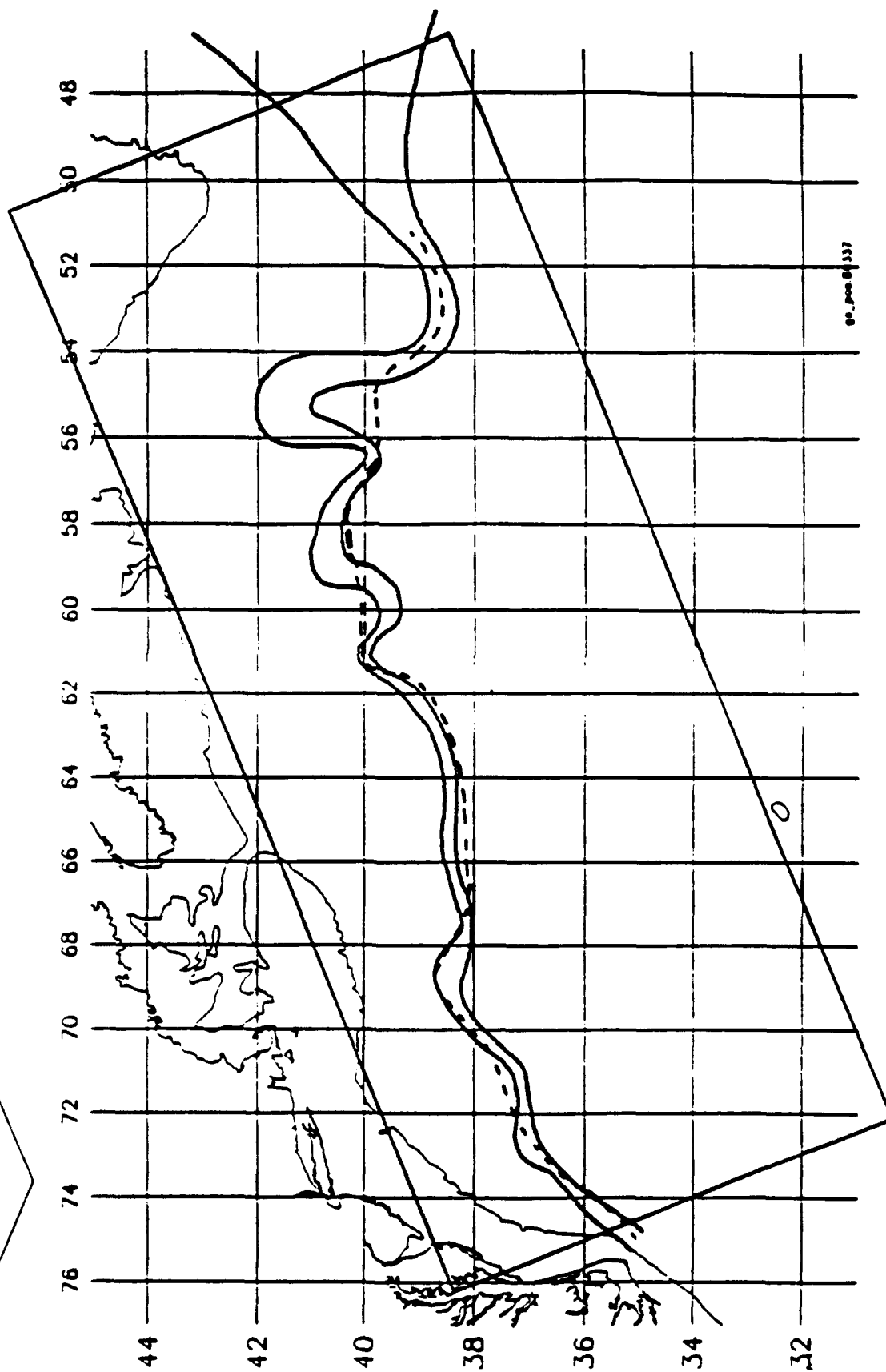


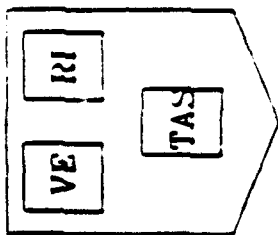
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GULF STREAM AXIS ERROR BARS.

FIGURE: NORTHERN & SOUTHERN EXTREMES.



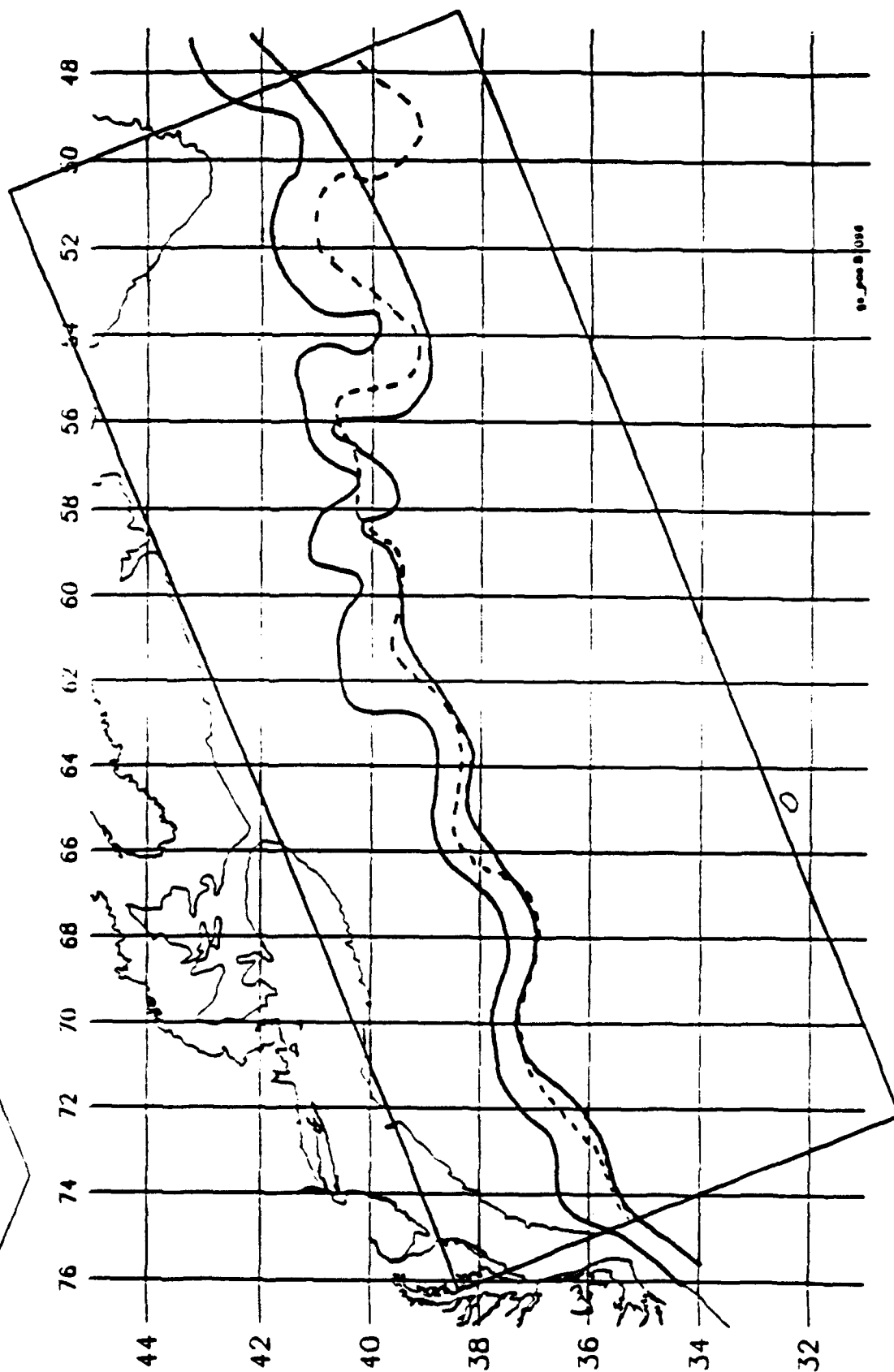


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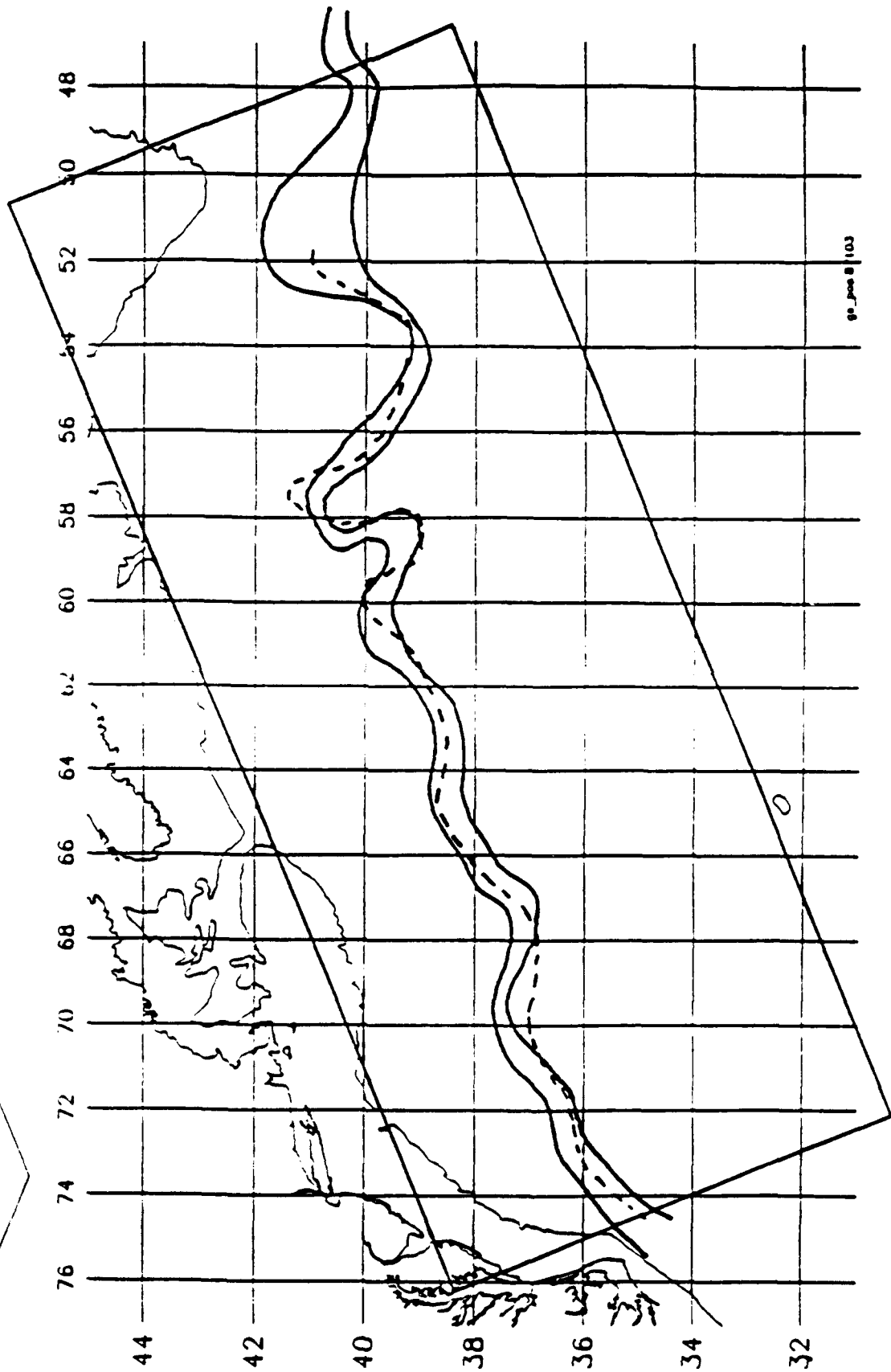
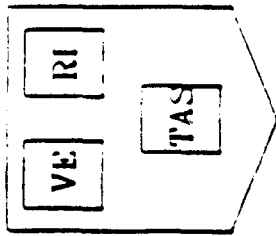
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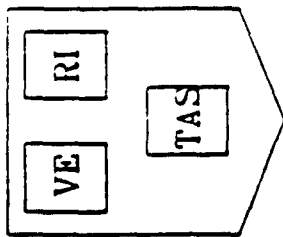
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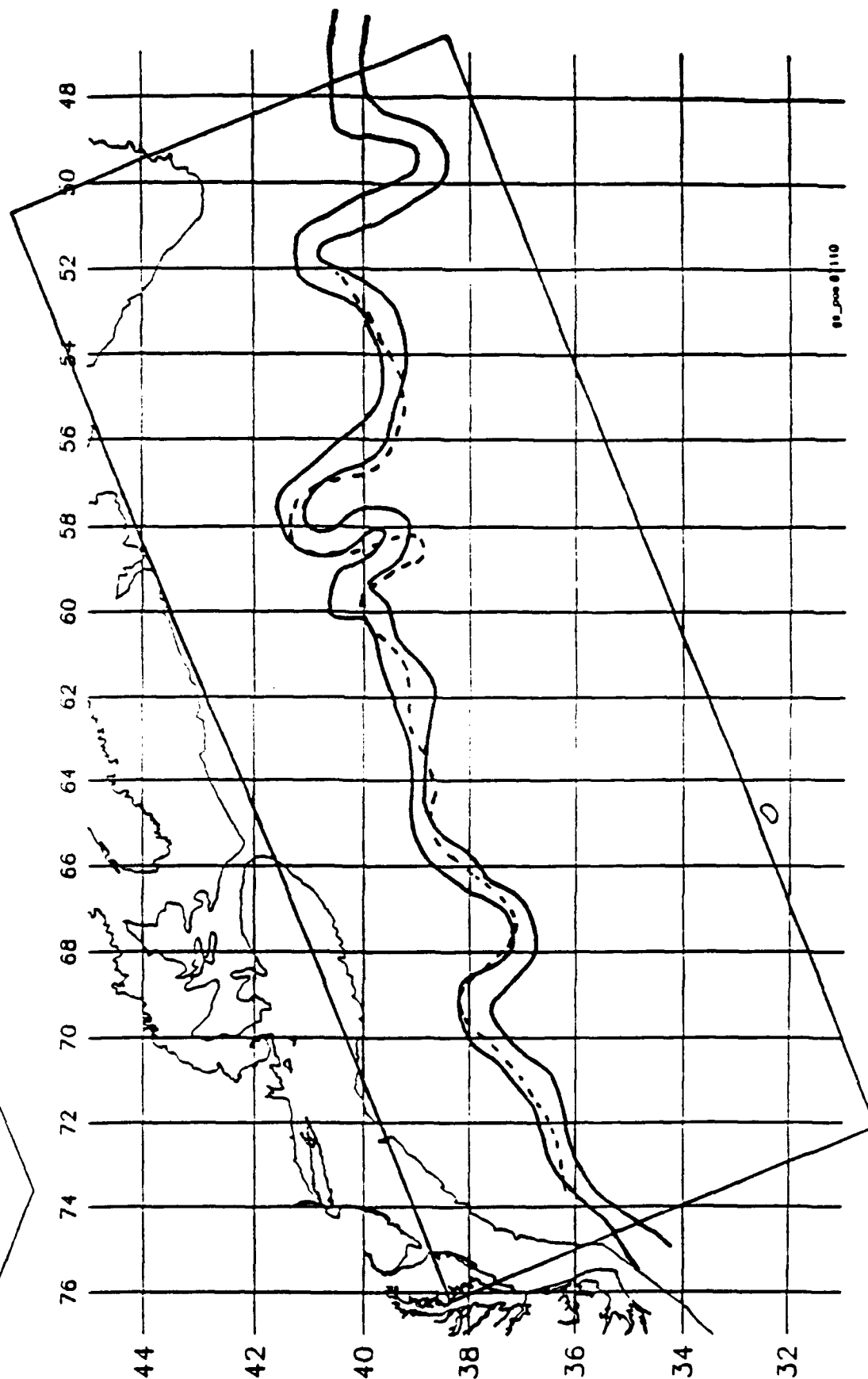


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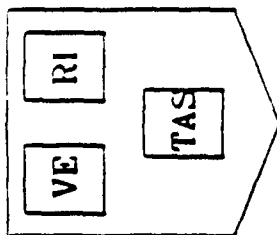
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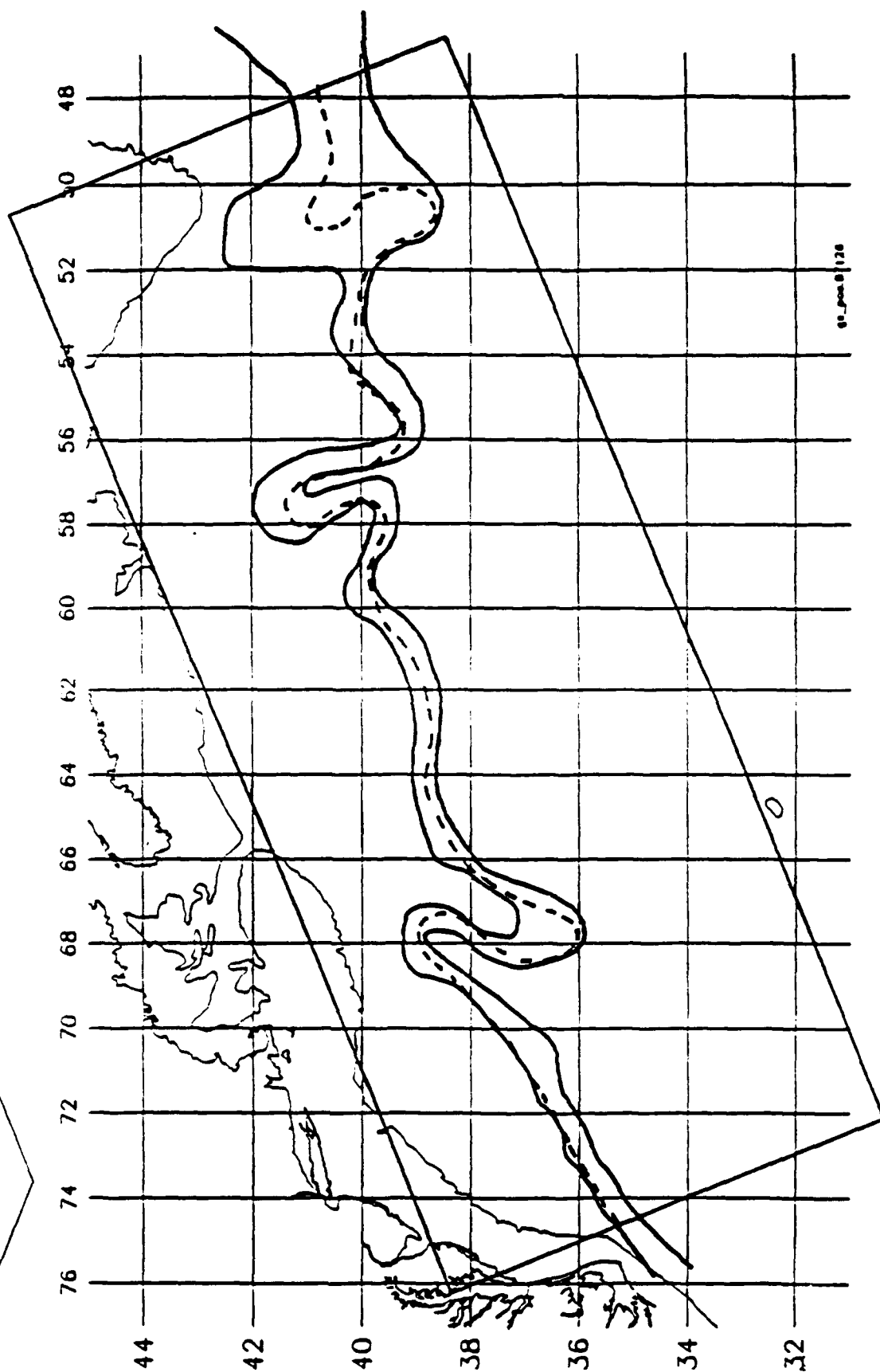


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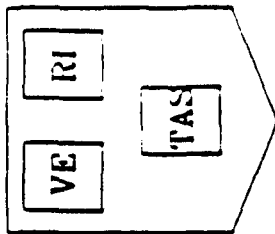
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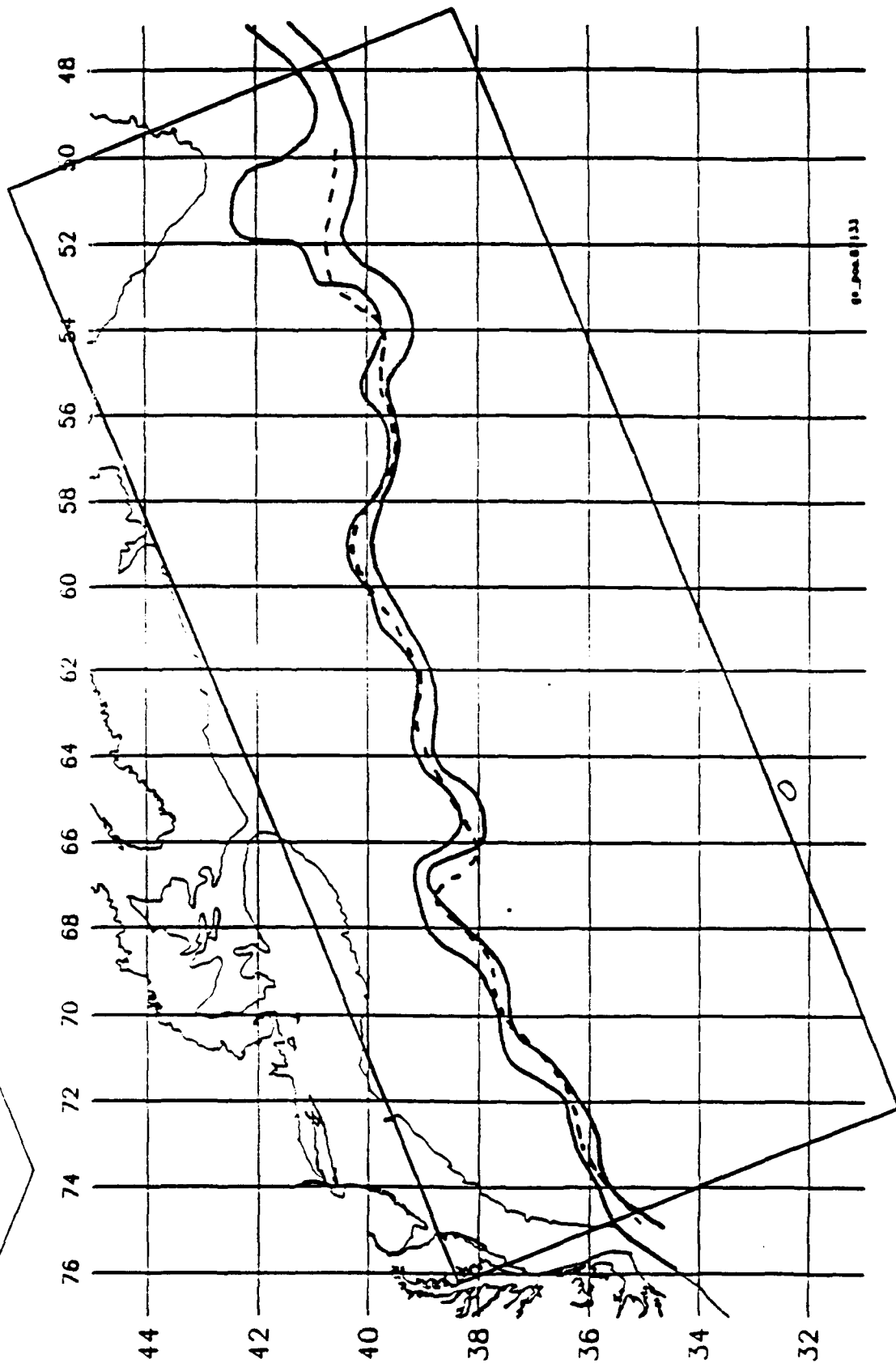


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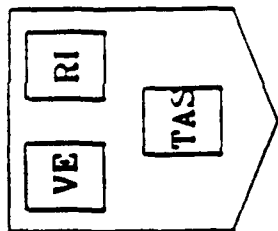
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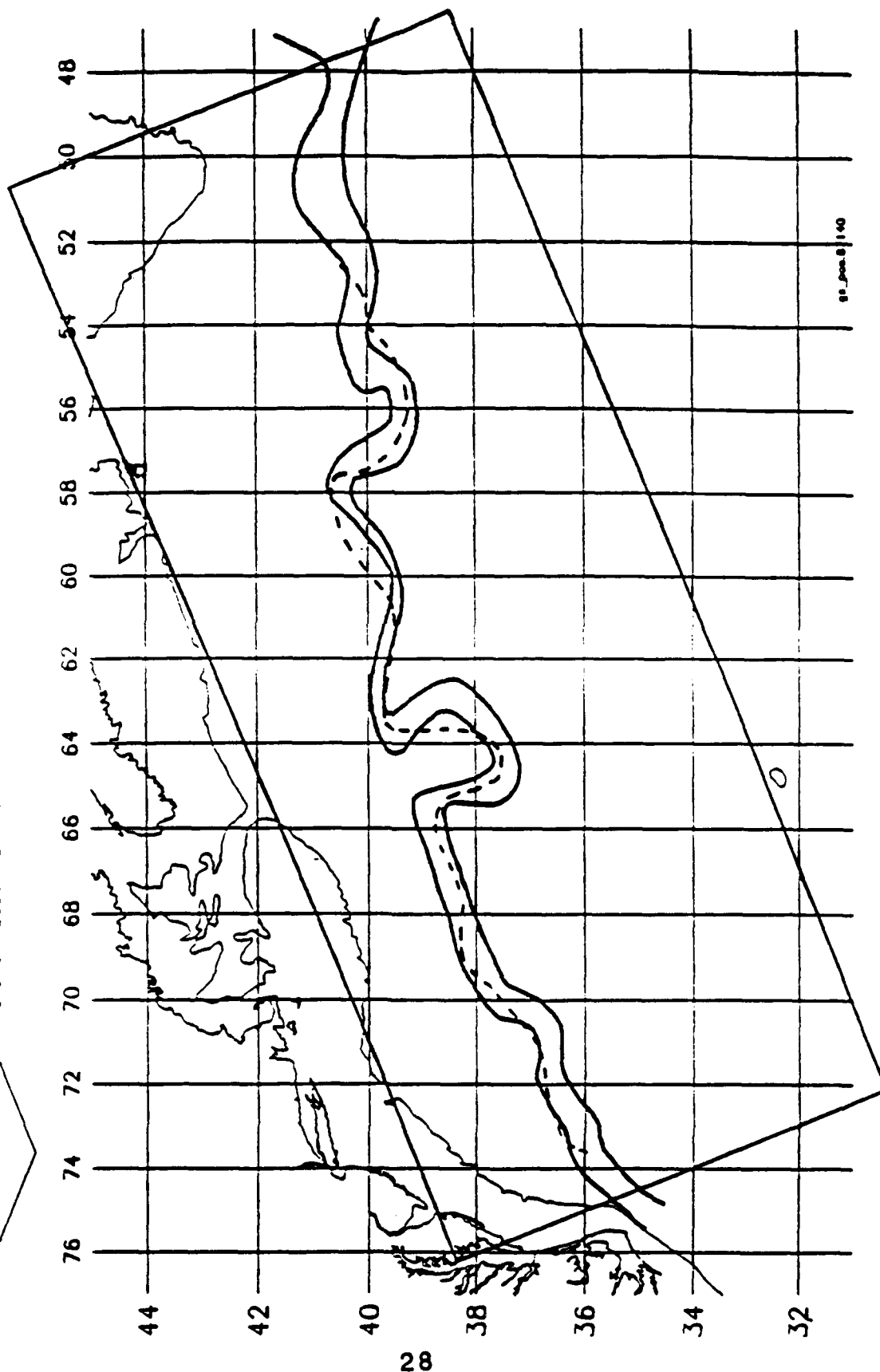


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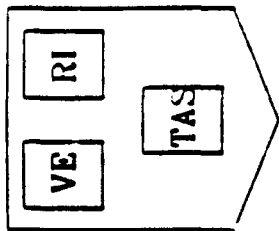
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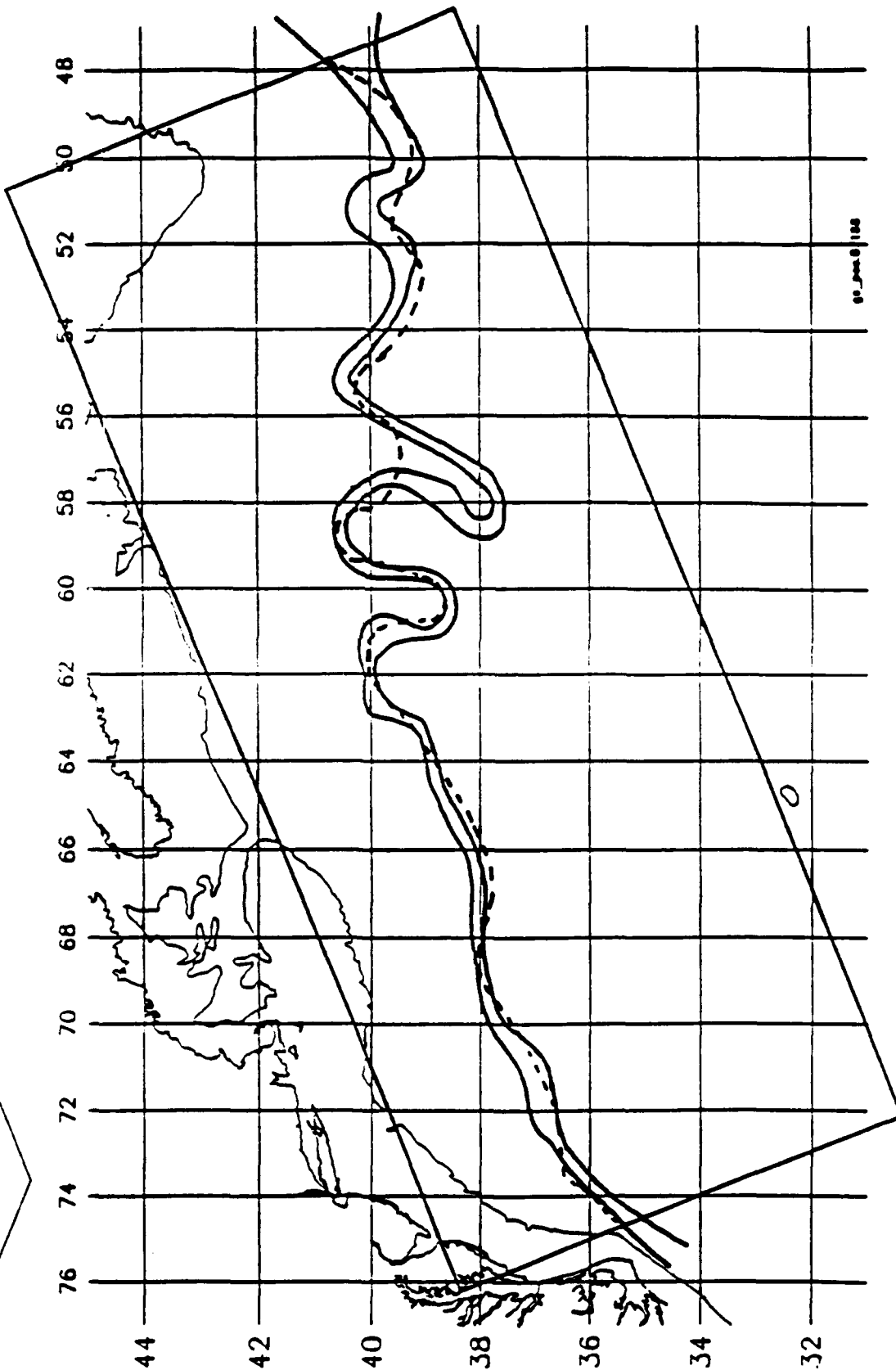


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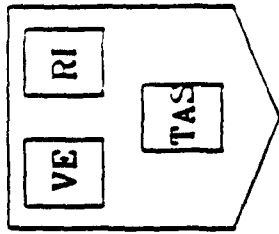
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FIGURE: NORTHERN & SOUTHERN EXTREMES.



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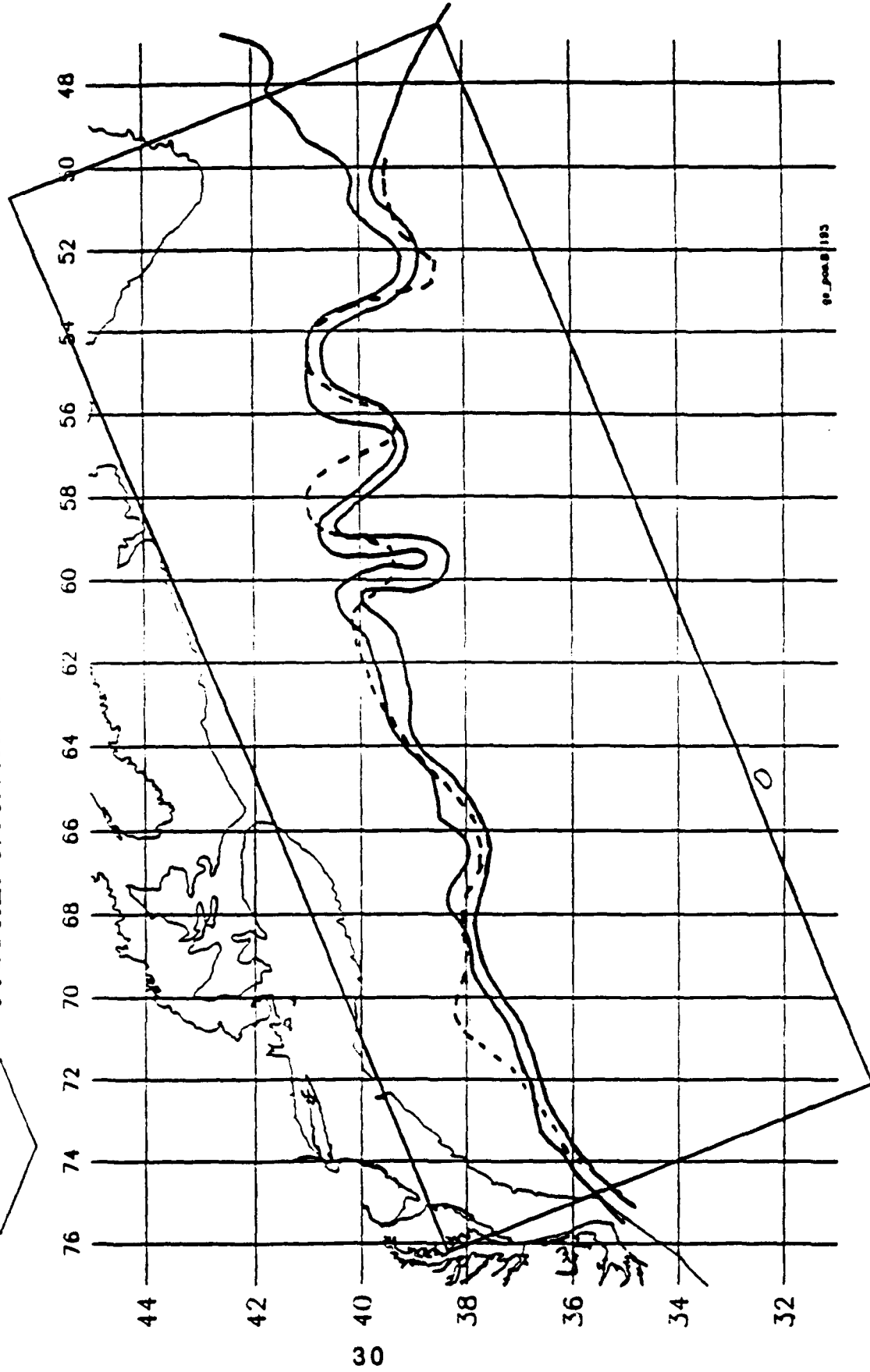


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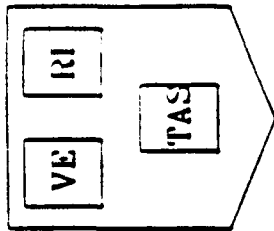
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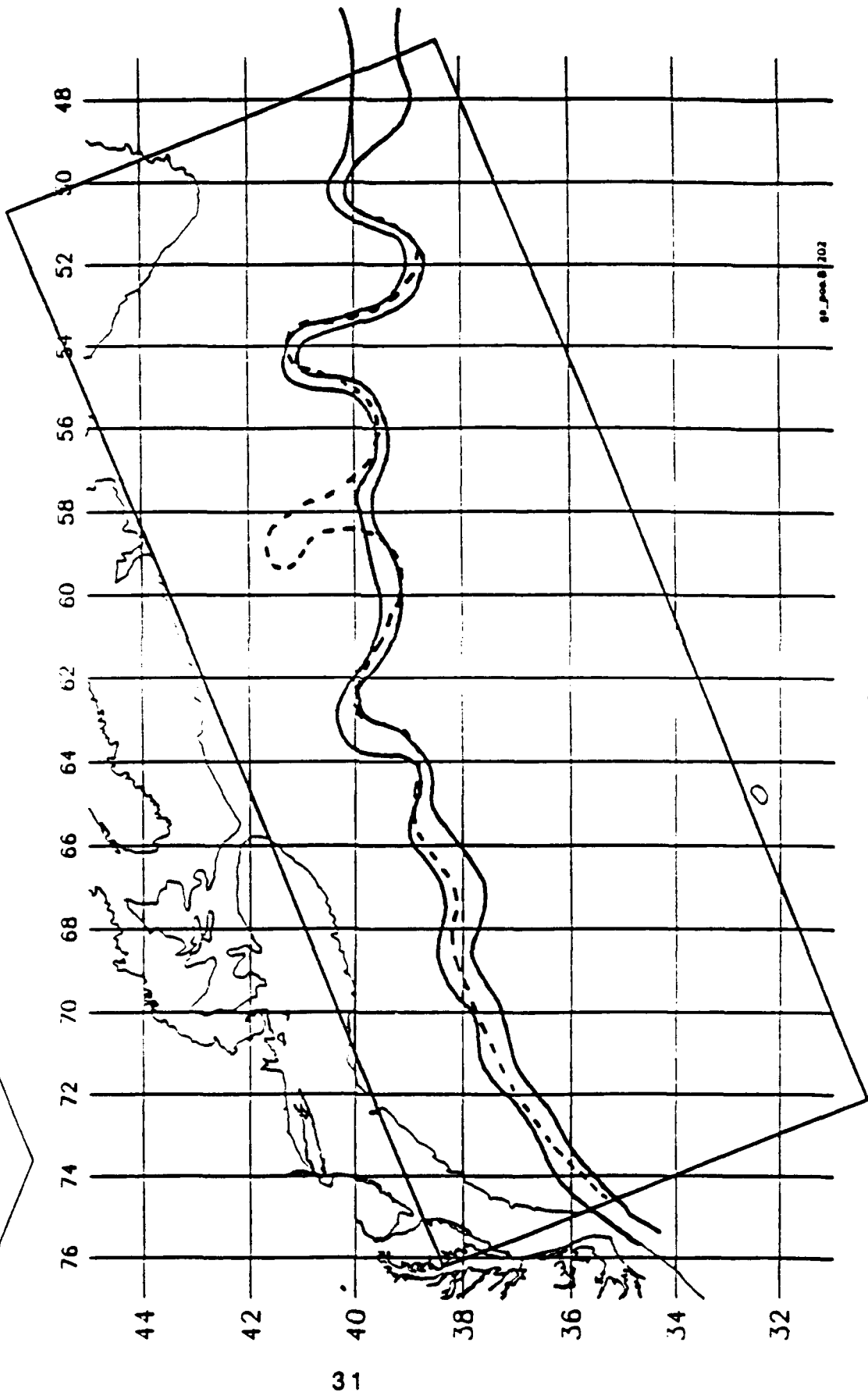


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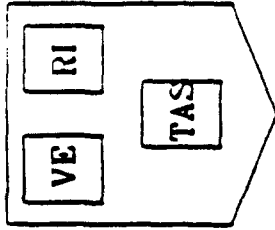
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FIGURE: NORTHERN & SOUTHERN EXTREMES.



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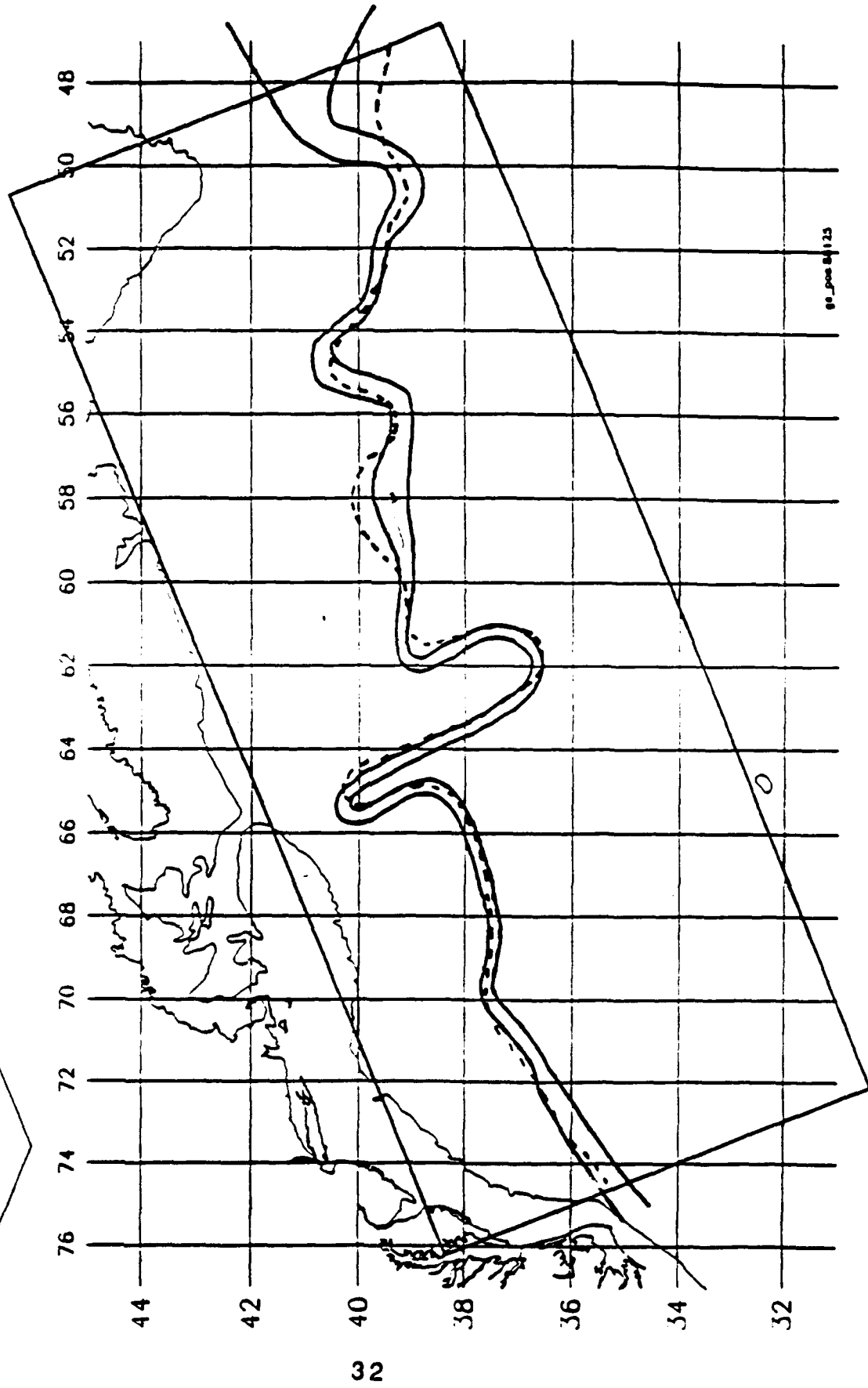


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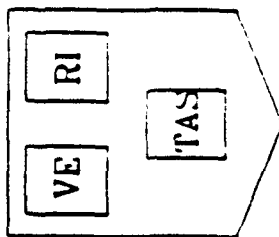
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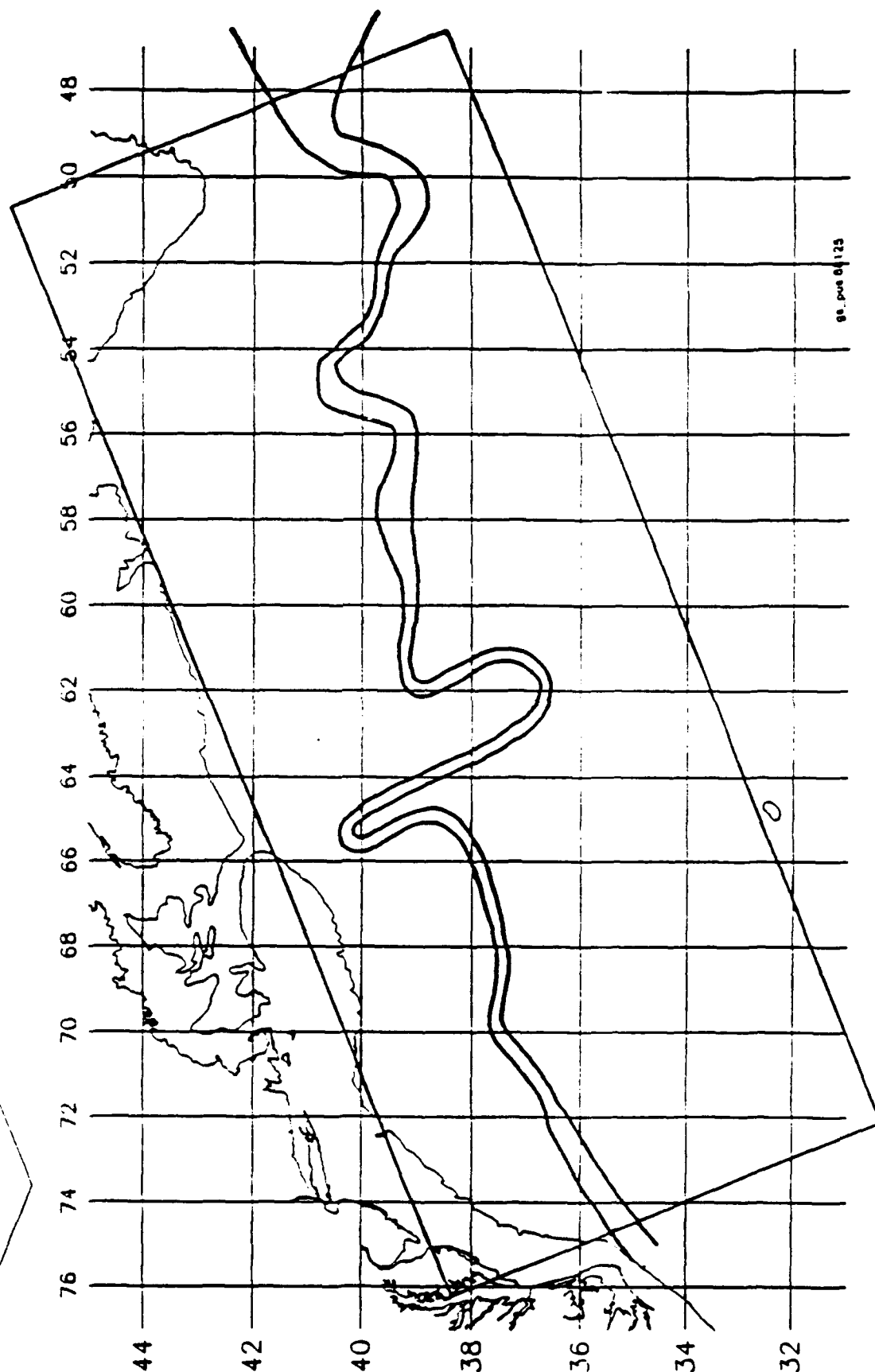


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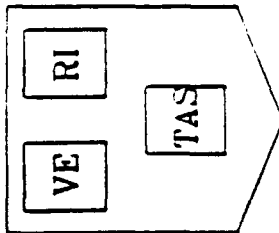
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FIGURE: NORTHERN & SOUTHERN EXTREMES.



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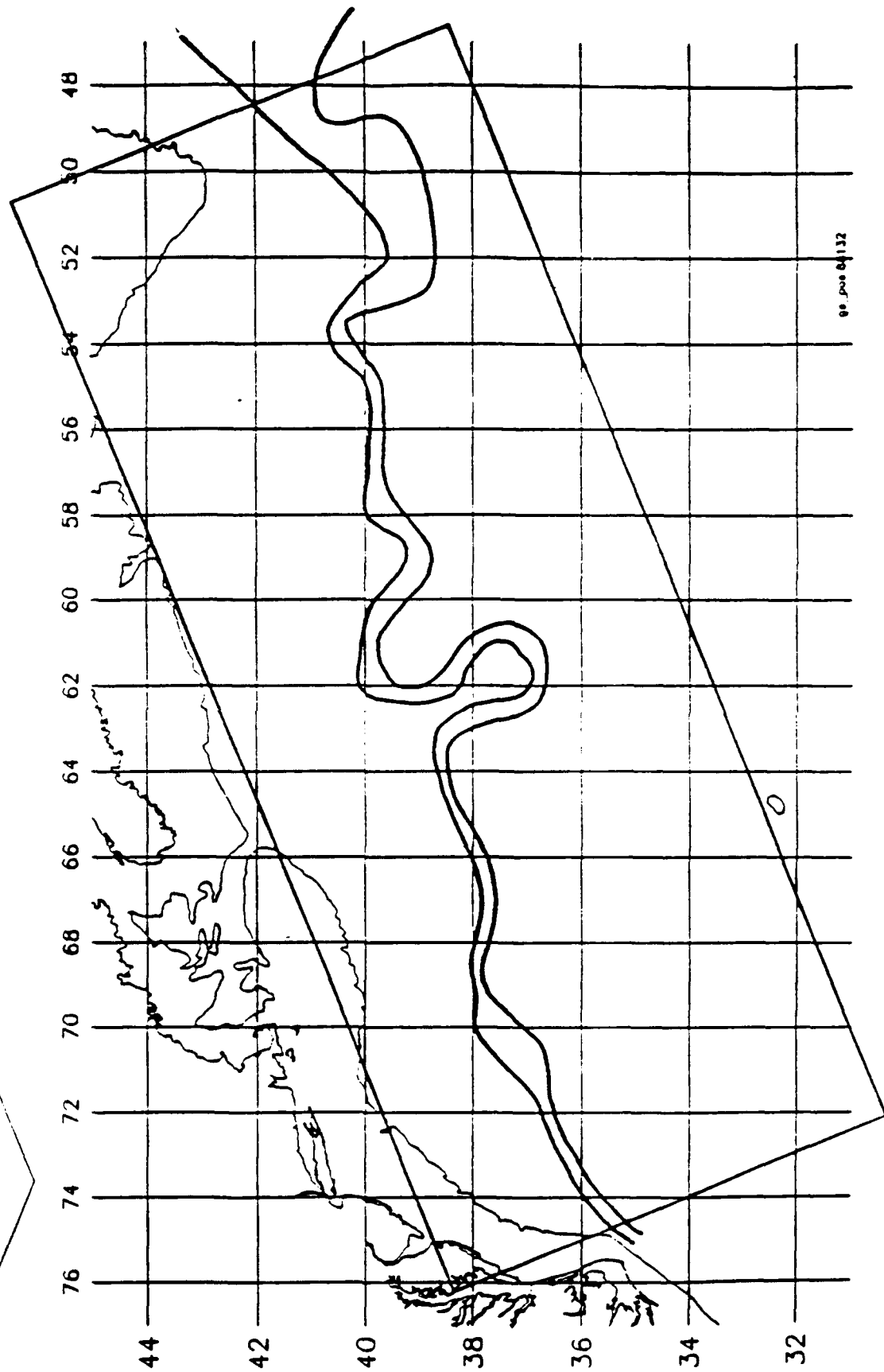


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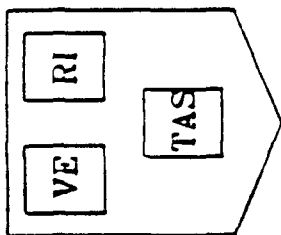
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FIGURE: NORTHERN & SOUTHERN EXTREMES.



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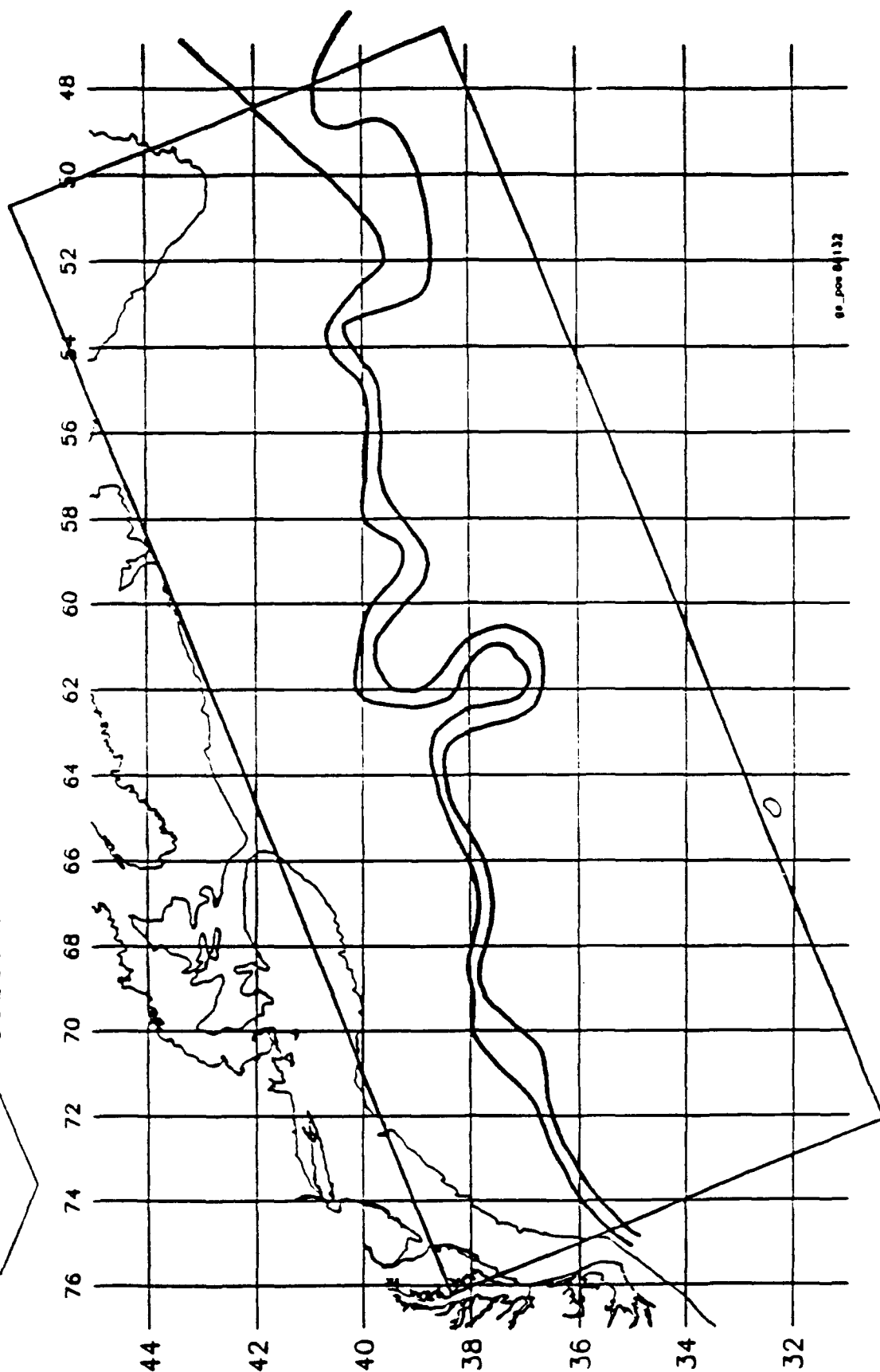


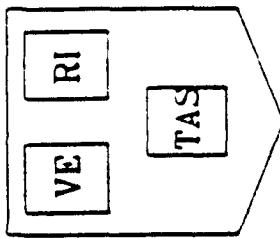
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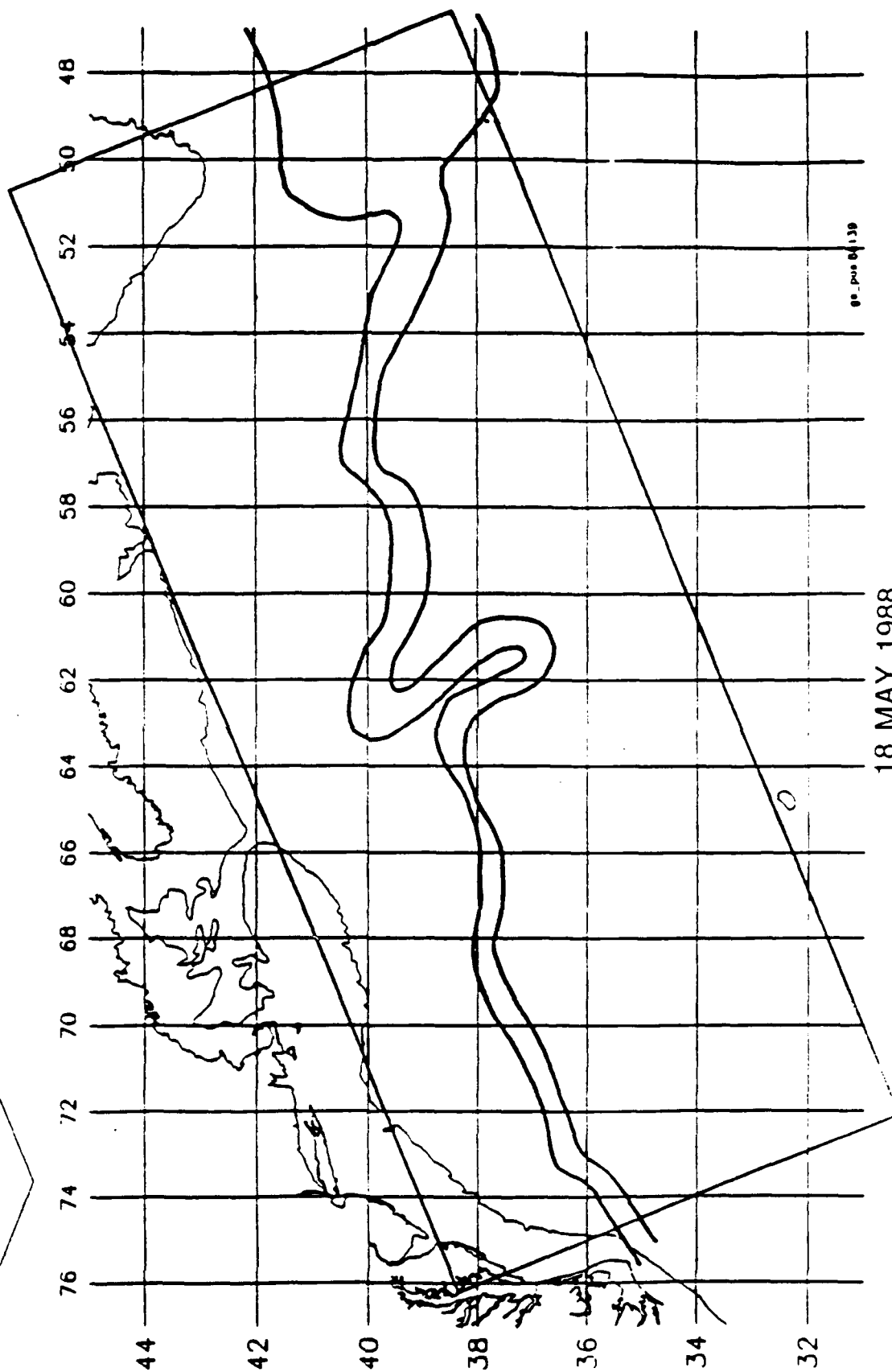


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13. Abstract (Maximum 200 words). The preparation of two-week duration case studies for the initialization and verification of Gulf Stream forecast models was begun jointly by Harvard and NOARL in 1988. The six case studies were chosen by determining which time periods had both the REX GEOSAT underflight AXBT surveys and good IR coverage. The data was used to generate Gulf Stream axis location and the warm and cold ring locations, spaced at one-week intervals. The analysis domain extended from approximately 74W to 54W. The strength of the total data set is that coverage by any single data set in this region is patchy. After preliminary tests, it was decided that additional data was needed to better locate the Stream axis. It was also necessary to add error bars on the frontal analysis. Preliminary comparisons of the NOARL and Harvard analyses indicated that, although some analyses agreed quite well, others were very different. INO wanted to use these data sets, but when differences were observed, INO sponsored the working meeting documented in this report, where these differences were either resolved, or when they lay within the error bars, so noted.					
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